Journal of the American College of Cardiology Vol. 49, No. 3, 2007

Published by Elsevier Inc.
ISSN 0735-1097/07/$32.00
doi:10.1016/j.jacc.2006.08.055

Comparison of Surgical Septal Myectomy and Alcohol Septal Ablation With Cardiac Magnetic Resonance Imaging in Patients With Hypertrophic Obstructive Cardiomyopathy

Uma S. Valeti, MD,* Rick A. Nishimura, MD,* David R. Holmes, MD,* Philip A. Araoz, MD,† James F. Glockner, MD,† Jerome F. Breen, MD,† Steve R. Ommen, MD,* Bernard J. Gersh, MB, ChB, DPhil,* A. Jamil Tajik, MD,* Charanjit S. Rihal, MD,* Hartzell V. Schaff, MD,‡ Barry J. Maron, MD§

Rochester and Minneapolis, Minnesota

Objectives This study sought to describe the acute morphologic differences that result from septal myectomy and alcohol septal ablation using cardiac magnetic resonance (CMR) imaging.

Background Surgical septal myectomy and alcohol septal ablation relieve left ventricular outflow tract obstruction in severely symptomatic patients with hypertrophic cardiomyopathy (HCM).

Methods Cine and contrast-enhanced CMR images were obtained in HCM patients before and after septal myectomy (n = 24) and alcohol septal ablation (n = 24). Location of septal reduction, extent of myocardial necrosis, and conduction system abnormalities with each technique were compared.

Results With septal myectomy, there was a discrete area of resected tissue consistently localized to anterior septum. In contrast, alcohol septal ablation resulted in a more variable effect. In most patients, alcohol septal ablation caused a transmural region of tissue necrosis, located more inferiorly in the basal septum than myectomy and usually extending into the right ventricular side of the septum at the midventricular level. However, there were 6 patients after alcohol septal ablation in whom there was sparing of the basal septum with residual gradients at follow-up. After the procedure, left bundle branch block developed in 46% of septal myectomy patients, and right bundle branch block was evident in 58% of alcohol septal ablation patients.

Conclusions Septal myectomy and alcohol septal ablation for severely symptomatic, drug-refractory patients with obstructive HCM have different morphologic effects and location sites on left ventricular septal myocardium. Septal myectomy provides consistent resection of the obstructing portion of the anterior basal septum, whereas the effect of ethanol septal ablation is more variable. These findings may have important implications for patient selection and management as well as long-term outcome. (J Am Coll Cardiol 2007;49:350–7) © 2007 by the American College of Cardiology Foundation

In an important subset of patients with hypertrophic cardiomyopathy (HCM), dynamic left ventricular (LV) outflow tract obstruction causes disabling heart failure symptoms (1,2). In patients unresponsive to pharmacologic therapy, surgical septal myectomy has been the accepted primary treatment intervention for relieving obstruction and improving symptoms (3–5). Alcohol septal ablation with a percutaneous catheter approach has recently emerged as a treatment alternative to surgery in selected patients (6,7).

See page 358

Although some clinicians regard these 2 strategies for ventricular septal reduction as comparable treatment modalities (8,9), there may be important differences between these 2 techniques, with potential impact on short-term and long-term outcome. In the present study, we investigated and compared the in vivo acute anatomical consequences after surgical septal myectomy and percutaneous alcohol

From the *Division of Cardiovascular Diseases, Mayo Clinic, Rochester, Minnesota; †Department of Radiology, Mayo Clinic, Rochester, Minnesota; ‡Division of Cardiovascular Surgery, Mayo Clinic, Rochester, Minnesota; and §The Hypertrophic Cardiomyopathy Center, Minneapolis Heart Institute Foundation, Minneapolis, Minnesota.

Manuscript received April 10, 2006; revised manuscript received July 5, 2006, accepted August 8, 2006.

septal ablation, using cine steady-state free precession and delayed contrast-enhanced images obtained by cardiac magnetic resonance (CMR) imaging.

Methods

Patient population. Patients with obstructive HCM who underwent alcohol septal ablation (between May 2003 and June 2005) or isolated surgical septal myectomy (between April 2004 and June 2005) and had both a pre-procedure and post-procedure CMR study were included in this study. Twenty-four patients with alcohol septal ablation and 24 patients with septal myectomy were prospectively studied with paired CMR studies and constitute the study group.

The clinical indication for surgery and ablation was an LV outflow tract gradient ≥50 mm Hg at rest or with provocation, and New York Heart Association (NYHA) functional class III or IV symptoms refractory to maximal medical management (4). Septal myectomy was offered as the primary treatment in these patients. Alcohol septal ablation was offered as an alternative for those patients who did not wish to undergo operation. The final choice of the therapeutic procedure (myectomy vs. ablation) was based on patient and physician preference after analysis of the individual clinical profile (including age) and full discussion of the risks and benefits of both procedures performed at Mayo Clinic.

During the time periods of the study, there were a total of 117 septal reduction procedures performed (47 alcohol septal ablation and 61 isolated myectomy procedures). Those patients not included in the study group had either implantable defibrillators or pacemakers in place, refused a CMR study because of claustrophobia or other reasons, or were otherwise judged clinically unsuitable for this protocol. In 7 of the 47 patients undergoing alcohol septal ablation, heart block developed requiring a permanent pacemaker, which excluded them from the study. No patients undergoing myectomy developed heart block. All subjects gave informed consent for the septal reduction procedures, and this study was approved by the institutional review board.

Septal myectomy technique. Surgical septal myectomy was performed using a modification of the procedure described by Morrow (5,10,11). Briefly, myectomy was performed through an aortotomy after induced cardiac asystole with cold blood cardioplegia. Myectomy creates a rectangular trough via 2 parallel incisions in the basal septum. These incisions are then connected proximally below the aortic valve and extended distally to beyond the level of mitral–septal contact and subaortic obstruction, and in some patients to the base of the papillary muscles (i.e., extended myectomy). Intraoperative transesophageal echocardiography was performed in all patients to document relief of obstruction and mitral regurgitation after myectomy (12).

Alcohol septal ablation technique. Alcohol septal ablation was performed as previously described (6,11). A temporary ventricular pacing catheter was placed via the right internal jugular vein before performing the ablation. Transeptal left heart catheterization was performed, and high-fidelity micromanometer-tipped catheters for continuous measurement of left atrial and LV pressures were placed. A multipurpose catheter was placed in the aortic root to measure the aortic pressure. Coronary angiography was performed to identify the appropriate septal perforator artery, which was then cannulated with a 0.014-inch guidewire. The most proximal septal artery that could undergo cannulation was selected as the initial artery. A low- to medium-compliance coronary angioplasty balloon was used to occlude the proximal septal perforator artery, and localization of the area of perfusion was performed using contrast echocardiography (11,13). One to 2 ml of 50% dilute Perflutren lipid microspheres were injected into the distal end of the balloon while imaging from the apical approach. If the area of perfusion on the septum was not the area of contact by systolic anterior motion of the mitral valve, another septal perforator was cannulated. One to 3 ml of absolute alcohol were injected slowly over 5 to 15 min into the septal perforator artery under echocardiographic guidance to cause a localized infarction. The direct pressure gradient between the LV and aorta was recorded continuously. A second perforator artery was cannulated and ablated if gradient reduction >50% was not achieved after the first septal ablation.

Abbreviations and Acronyms

CMR = cardiac magnetic resonance
ECG = electrocardiogram
HCM = hypertrophic cardiomyopathy
LBBB = left bundle branch block
LV = left ventricular
NYHA = New York Heart Association
RBBB = right bundle branch block

CMR imaging. Cardiovascular magnetic resonance imaging was performed before myectomy or ablation and again 3 to 7 days after the procedure in all patients. All scans were performed on a 1.5-T GE Signa Excite Twin Speed clinical scanner (General Electric Medical Systems, Milwaukee, Wisconsin) using a 4- or 8-element cardiac phased-array receiver coil. Images were acquired using electrocardiogram (ECG) gating during multiple short breath holds (8 to 15 s).

Functional performance of the ventricles was assessed using cine steady-state free-precession images. An initial 4-chamber view was obtained, followed by multiple parallel short-axis slices (8-mm slice thickness, 2-mm gap) every 10 mm covering the entire ventricle from base to apex. To perform a detailed assessment of the dynamics of mitral–septal interaction, we obtained 10 radial long-axis views 10° apart to cover the entire LV outflow tract (a basal short-axis slice was used as a reference to prescribe the radial slices). Typical scan parameters for the ECG-gated segmented k-space steady-state free-precession sequence were as follows: repetition time/echo time/temporal resolution/matrix/flip angle/bandwidth/views per segment 3.5 ms/1.6 ms/40 ms/224 × 160/45°/125 kHz/8 to 16.

Delayed-enhancement images for detection of tissue necrosis were obtained approximately 10 min after injection of intravenous gadolinium-diethylenetriaminepentaacetic acid (0.2 mmol/kg) using a segmented inversion recovery prepared fast gradient echo sequence (14). The prescription for this sequence was identical to the short-axis cine sequence to ensure image registration. Typical scan parameters were as follows: repetition time/echo time/inversion time/matrix/flip angle/bandwidth/views per segment 6.5 ms/3.1 ms/175 to 225 ms/256 × 192/20°/31.2 kHz/24.

Analysis of CMR images. SHORT-AXIS CINE IMAGES. Short-axis cine images were used to calculate maximal LV wall thickness and mass based on endocardial and epicardial contours traced at end-diastole. Papillary muscles and prominent trabeculations were included in the mass calculations. The LV ejection fraction was calculated based on endocardial contours traced using computer-assisted planimetry at end-diastole and end-systole.

LOCALIZATION AND QUANTITATION OF SEPTAL REDUCTION SITE. For the purpose of analysis, ventricular septum was divided into anterior and inferior segments and LV free wall as previously described (15). The area of septal reduction in myectomy patients was identified from the short-axis and radial long-axis cine images as a distinctive trough in the basal anterior septum. In patients who underwent alcohol ablation, the tissue necrosis site was visualized as a region of hyperenhancement on the post-gadolinium contrast-enhanced images.

The area of tissue necrosis after alcohol septal ablation was calculated by the Simpson method using planimetry of the hyperenhanced area on the delayed contrast-enhanced scans. New areas of hyperenhancement on the post-ablation CMR (i.e., not present on the pre-ablation scan) were considered to represent tissue necrosis caused by the procedure (16). Areas of hyperenhancement identified in the pre-procedural scans were attributed to pre-existing fibrosis and were not included in the calculation of the infarct mass (17). Central areas of hypoenhancement within the region of hyperenhancement were judged to be central no-flow zones in the core of tissue necrosis, and were included in the calculation of the tissue necrosis size. Hyperenhancement involving >75% of the thickness of the septum was regarded as near transmural.

Preprocedural and post-procedural images were by design analyzed side-by-side (to accurately match cross-sectional slices) and interpreted without prior knowledge of whether the patients had undergone either myectomy or ablation, and as the consensus of 2 observers (U.S.V. and P.A.A.). Because of the differences in the post-procedure CMR images between septal ablation and septal myectomy, blinding was not possible. All contours were manually drawn and analyzed using a standard commercially available software package (MASS 5.0, Medis Medical Imaging Systems, Leiden, the Netherlands).

ECG. Resting 12-lead ECGs were obtained before and 24 h after the procedure and were analyzed for conduction abnormalities blindly without knowledge of the CMR findings. The abnormal patterns coded were left bundle branch block (LBBB), right bundle branch block (RBBB), and intraventricular conduction delay.

Statistics. An unpaired Student *t* test was used to compare continuous variables between the 2 groups, and chi-square analysis was used to compare categorical variables. Statistical significance was defined as $p < 0.05$.

Results

Demographics and procedural results. PATIENT POPULATION. Demographics of the 2 patient populations are shown in Table 1. In comparison to the ablation group, patients undergoing myectomy were younger (50 ± 20 years vs. 62 ± 12 years, p = 0.03). Pre-procedural LV outflow gradients were similar (75 ± 41 mm Hg vs. 76 ± 40 mm Hg, p = NS). Nineteen patients undergoing myectomy and 18 patients undergoing ablation had resting gradients >50 mm Hg. The remaining patients had provocable gradients >50 mm Hg using amyl nitrite (7 patients), isoproterenol (3 patients), and exercise (1 patient).

SURGICAL MYECTOMY. In the 24 myectomy patients, LV outflow tract gradients measured in the operating room decreased from 75 ± 41 to 3 ± 3 mm Hg immediately after myectomy. The amount of resected muscle was 6 ± 4 g by weight. The ECGs performed 24 h after the procedure showed complete LBBB in 11 of 24 patients (46%), and no patient developed heart block.

ALCOHOL SEPTAL ABLATION. Alcohol septal ablation was performed using the first septal perforator artery in 20 of 24 patients; 3 patients required ablation of both the first and second septal perforators, and another patient had ablation of a septal perforator originating from the proximal circumflex artery. The mean volume of alcohol injected was 1.7 ± 0.4 ml. The LV outflow gradient as measured in the catheterization laboratory decreased

Table 1 Clinical Features of Hypertrophic Cardiomyopathy Patients With Surgical Myectomy or Alcohol Septal Ablation

	Septal Myectomy (n = 24)	Alcohol Septal Ablation (n = 24)
Age (yrs)	50 ± 20	62 ± 12*
Gender (male/female)	15/9	12/12
LVOT gradient preprocedure (mm Hg)	75 ± 41	76 ± 40
LVOT gradient immediately postprocedure (mm Hg)	3 ± 3	7 ± 6
Ventricular septal thickness preprocedure (mm)	22 ± 4	23 ± 4
LV mass preprocedure (g)	220 ± 88	216 ± 104
Ejection fraction preprocedure (%)	68 ± 7	69 ± 9

Values are expressed as mean ± SD. *p < 0.05 versus septal myectomy.
LV = left ventricular; LVOT = left ventricular outflow tract.

from 76 ± 40 to 7 ± 6 mm Hg immediately after the procedure. The ECGs performed 24 h after the procedure showed that 14 patients (58 %) developed RBBB, 1 a complete LBBB, and 1 transient LBBB. Mean troponin T values 36 h after the ablation were 2.35 ± 0.83 ng/ml. Of the total of 47 ablations performed during this time period, 8 patients had heart block requiring permanent pacemakers (17%). These 8 patients were a priori excluded from the study because a post-procedure CMR could not be performed.

Site and extent of septal reduction by CMR. MYECTOMY. The myectomy site was confined to the LV aspect of the basal anterior septum in all 24 patients (Figs. 1 and 2). In 14 patients the septal resection extended distally into the midventricle in anterior septum at the papillary muscle level. Septal thickness at the site of resection site was 22 ± 5 mm (range 16 to 33 mm) preoperatively and decreased to 11 ± 4 mm (range 5 to 20 mm) postoperatively.

ALCOHOL SEPTAL ABLATION. The site of targeted septal reduction with alcohol ablation differed morphologically from that of myectomy with respect to location and extent (Figs. 1 and 3). The extent and distribution of the tissue necrosis was variable. In 18 of 24 patients, the tissue necrosis was transmural and located predominantly at the junction of anterior and inferior septum in the basal LV, and extended into the inferior portion of the septum at the midventricular level involving primarily the right ventricular portion. In comparison with the septal region resected by septal myectomy, this area of tissue necrosis was more inferior within the septum (Fig. 3). In 5 patients the most proximal basal septum was unaffected by the alcohol septal ablation with the tissue necrosis involving a more distal area of the septum. In these 5 patients, the tissue necrosis involved primarily the right ventricular side of the septum (Fig. 4). In 1 patient, the tissue necrosis was not transmural and confined to the LV side of the septum.

The calculated proportion of LV mass occupied by tissue necrosis was 8 ± 4% (range 3.6% to 13.6%); the average estimated size was 16 ± 7 g. Each of the 24 patients also had central areas of hypoenhancement within the hyperenhanced infarct area, representing no-flow zones of variable sizes in the core of the tissue necrosis (Fig. 3). The prominent differences between these 2 septal reduction techniques are summarized in Table 2.

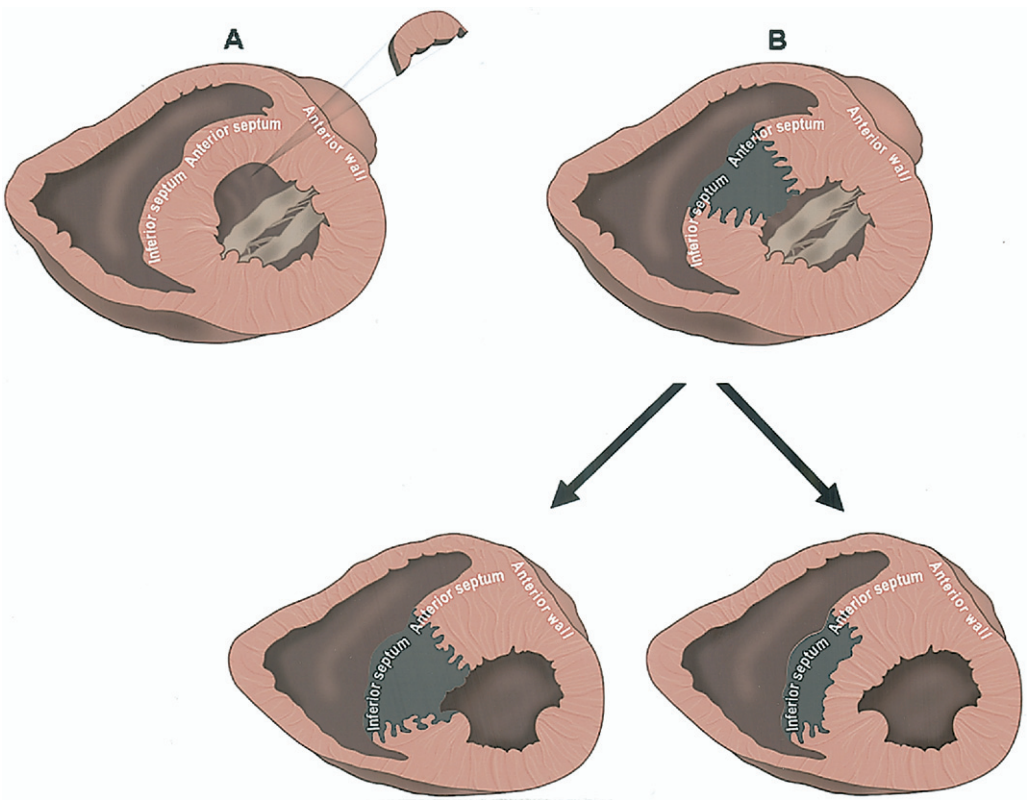

Figure 1 **Schematic Representation of the Differing Effects of Septal Reduction Therapies**

Contrasting anatomical consequences of extended surgical septal myectomy shown in the short-axis plane **(A)** and alcohol septal ablation **(B)**. **(A)** The tissue resected at myectomy is from the left ventricular side of the basal anterior septum. **(B)** The tissue necrosis resulting from alcohol ablation is usually transmural and located more posteriorly and inferiorly in the basal anterior septum than is the case for myectomy. At midventricular level **(lower row of B)**, the tissue necrosis involves the inferior septum either with transmural distribution or predominantly the right ventricular portion of the septum.

JACC Vol. 49, No. 3, 2007
January 23, 2007:350–7

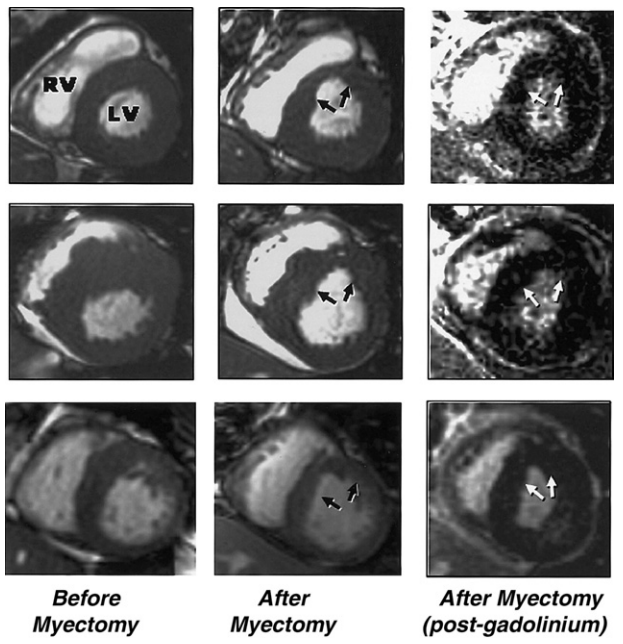

Figure 2 CMR Image in Surgical Myectomy Patients

Short-axis plane cardiovascular magnetic resonance (CMR) image of the basal left ventricle (LV) from 3 hypertrophic cardiomyopathy patients showing the area of septal myectomy before **(left)**, 3 to 7 days after surgery **(center)**, and also 3 to 7 days after myectomy after the administration of gadolinium **(right)**. **Arrows** show the area and extent of the muscular septal resection. In the post-gadolinium images, normal myocardium appears **dark** and necrotic (infarcted) myocardium appears **white**. There is no evidence of intramyocardial delayed hyperenhancement at or near the myectomy site, indicating the absence of necrotic tissue. RV = right ventricle.

Short-term follow-up. Combined clinical and echocardiographic follow-up was obtained in 45 of 48 patients (94%). There were 23 of 24 myectomy and 22 of 24 alcohol septal ablation patients in whom this follow-up could be obtained. The mean follow-up time was 440 ± 180 days.

MYECTOMY. All 23 patients have remained symptom free and without recurrence of gradients at follow-up. No patient required a permanent pacemaker. One patient developed a left hemispheric stroke 2 weeks after the myectomy. The mean follow-up LV outflow tract gradient was <20 mm Hg in all 23 patients (mean 7 ± 6 mm Hg). No patient has required a repeat procedure.

ALCOHOL SEPTAL ABLATION. There were no deaths in the 22 patients in whom both clinical and echocardiography follow-up could be obtained. One patient developed symptomatic sustained ventricular tachycardia 2 weeks after discharge requiring electrophysiological ablation of the tachycardia. There were 16 patients who had improvement of symptoms with a residual resting LV outflow gradient <20 mm Hg. Six patients had a residual resting LV outflow gradient >20 mm Hg. One of these patients underwent septal myectomy for severe residual symptoms at 6-month follow-up. Two other patients remained in NYHA functional class 3 but elected to continue medical therapy. Two patients had residual NYHA functional class 2 symptoms and elected to continue medical therapy. One patient had dramatic improvement in symptoms but had a resting gradient >100 mm Hg at follow-up.

Of the 6 patients with residual LV outflow gradients, the immediate post-procedure CMR had shown that 5 had sparing of the basal septum. Of these 5 patients with sparing of the basal septum, 4 had nontransmural tissue necrosis of the right ventricular side of the septum (Fig. 4). There was 1 patient with a residual gradient who was shown to have a small nontransmural region of tissue necrosis that involved only the LV side of the septum and the basal anterior wall.

Follow-up CMR studies were obtained in 10 patients at an average of 6 months (176 ± 11 days). The mean reduction in septal thickness was 6 mm. The mean thickness at the site of tissue necrosis before procedure was 23 ± 4.5 mm (range 17 to 29 mm) and decreased to 17 ± 5 mm (range 13 to 25 mm) at follow-up. In the patients with sparing of the basal septum on the immediate post-procedure CMR scan, there was thinning of the more distal

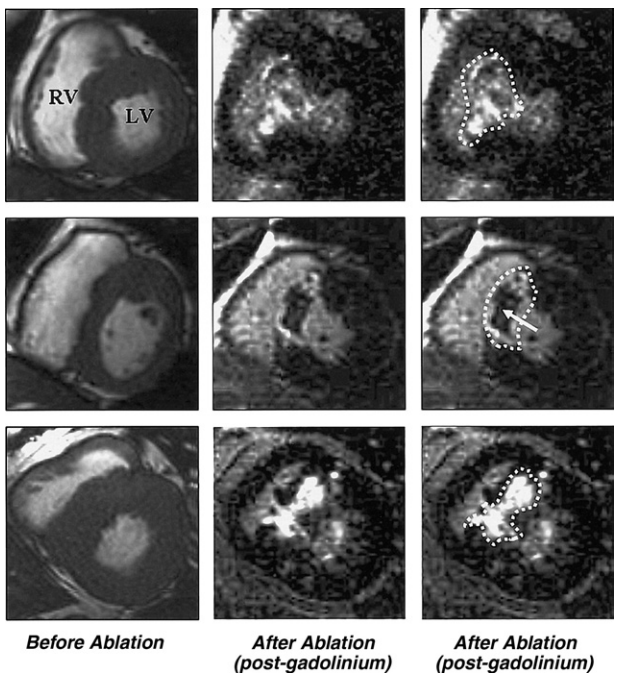

Figure 3 CMR Image in Alcohol Ablation Patients

Short-axis plane cardiovascular magnetic resonance (CMR) image of the basal left ventricle (LV) from 3 hypertrophic cardiomyopathy patients showing pre-ablation morphology **(left panels)** and the area of the septal ablation created by infusion of alcohol on the post-gadolinium images **(center, right panels)**. The images in the **right panel** are identical to those in the **center panel** and highlight the area of the infarct with **broken lines**. Post-ablation images (after gadolinium) show large areas of transmural hyperenhancement with irregular borders, indicative of necrotic tissue **(white)** in the region of the targeted ablation. **Arrow** shows an inhomogeneous area within the core of an infarct in which gadolinium uptake is absent because of severe microvascular obstruction **(center patient)**. RV = right ventricle.

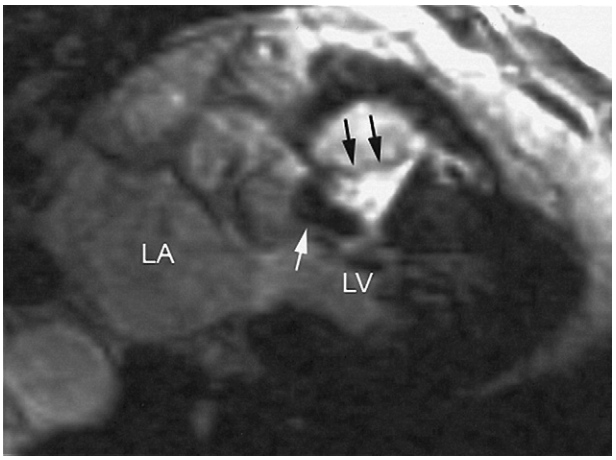

Figure 4 CMR Image After Septal Ablation With Residual Obstruction

Long-axis cardiovascular magnetic resonance (CMR) image views after alcohol septal ablation on a post-gadolinium study. There is sparing of the proximal basal septum **(white arrow)**. The region of the hyperenhancement involves mainly the right ventricular side of the ventricular septum **(black arrows)**. This patient had the most proximal septal perforator cannulated with apparent localization to the basal septum on contrast echocardiography during the ablation procedure. LA = left atrium; LV = left ventricle.

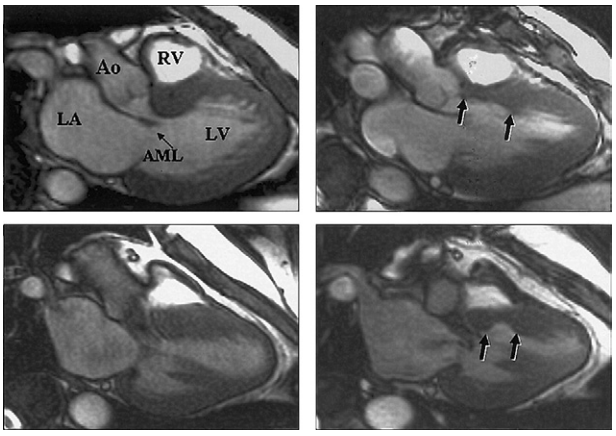

Figure 5 CMR Image After Septal Myectomy Versus Septal Ablation

Top panels show long-axis cardiovascular magnetic resonance (CMR) imaging views before **(left)** and after **(right)** septal myectomy. The portion of basal septum evident in this plane, projecting into the left ventricular (LV) outflow tract, has been resected at myectomy **(arrows)**. **Bottom panels** show long-axis views before **(left)** and 5 months after **(right)** septal ablation. The ablation has spared the most proximal portion of basal septum at the level of systolic anterior motion and mitral valve-septal contact, involving only the more distal septum below this level of obstruction **(arrows)**. AML = anterior mitral leaflets; Ao = aorta; LA = left atrium; RV = right ventricle.

septum with the basal septum remaining unchanged in thickness (Fig. 5).

Discussion

The purpose of the present investigation was to compare the anatomical sequelae of surgical septal myectomy versus alcohol septal ablation using CMR. There were substantial differences in the anatomical effects of these 2 techniques involving both the location and extent of myocardial involvement. These findings explain the differences in the acute outcomes of these techniques and may have important implications regarding long-term outcomes.

With septal myectomy, there was a discrete area of resected tissue localized to the anterior septum. The region of septal reduction was a consistent finding in all patients. There was a 50% reduction in thickness of the basal septum. At follow-up, the residual gradient was <20 mm Hg in all patients, and all patients were asymptomatic.

Alternatively, there was a more varied effect of alcohol septal ablation. In 75% of patients there was a transmural region of tissue necrosis located inferiorly in the basal septum, extending onto the right ventricular side of the septum at the midventricular level. The amount of tissue necrosis was variable but averaged 8% of overall LV mass, which is similar to that reported by Van Dockum et al. (18,19). Although the most proximal septal perforator artery was initially used with echocardiographic contrast guidance during performance of the alcohol septal ablation, there were 6 patients who had sparing on the proximal basal septum with residual gradients at follow-up. These patients had a nontransmural tissue necrosis, usually involving the right ventricular side of the septum. The suboptimal results associated with right ventricular septal infarction have been described previously (18,19). The average overall reduction in basal septal thickness was 26%.

Clinical implications. The major finding in our study was the uniform resection of proximal basal septal muscle in the anterior distribution by septal myectomy, resulting in complete relief of obstruction in all patients. This consistent area of resection is related to the direct visualization of the

Table 2 Comparison of Anatomical Differences Between Surgical Myectomy and Alcohol Septal Ablation

	Septal Myectomy	Alcohol Septal Ablation
Site of septal reduction	Left ventricular side of the septum at basal and midventricular level	More inferior location in basal and midventricular septum, usually extends into right ventricular side of septum at midventricular level
Depth of resection/ablation	Average depth = 10 mm	Predominantly transmural in basal septum; usually nontransmural in midventricular septum
Mass of resection/ablation	6 ± 4 g	16 ± 7 g
Resection/ablation of protruding basal septum	All patients	Most proximal basal septum spared in 25% of patients

obstructing septum at the time of operation. This is opposed to alcohol septal ablation, in which there was a more variable location of the area of necrosis. In alcohol septal ablation the operators are still confined to the anatomical distribution of the available septal perforator arteries, and there may not be an artery that can be cannulated that supplies directly the basal septum. The use of echocardiographic contrast to guide selection of a septal perforator has been proposed to ensure that the area of the tissue necrosis is the region of the obstruction (13,20). This echocardiographic contrast guidance may be affected by acoustic shadowing, and thus the very basal septal region may not be able to be consistently assessed using echocardiographic contrast guidance.

At follow-up, there was an overall higher residual obstruction after septal ablation versus septal myectomy. This in part is because of the patients in whom the ablation spared the basal septum. However, the location of septal reduction by these 2 techniques may also influence the outcome. The region of systolic anterior mitral valve to septal contact is usually located in a more anterior region of the septum, with the obstruction formed by the anterior septum, anterior free wall, and mitral valve. This is the region that is directly targeted by septal myectomy. Alcohol septal ablation targeted a more inferior region of the ventricular septum.

The location of the septal reduction by myectomy and ablation explains the differential effects on the conduction system (11,21). The course of the right bundle branch is along the right ventricular side of the inferior septum, and thus is frequently damaged by the transmural region of tissue necrosis produced by septal ablation, as occurred in about one-half of our patients who developed RBBB. Complete heart block has been reported in 10% to 20% of patients after septal ablation when additional segments of the left bundle branch are affected. In contrast, septal myectomy interrupts the left bundle branch coursing in the anterior septum. Complete heart block is particularly uncommon in the absence of pre-existing RBBB (<1%) because the right bundle branch is rarely affected by the muscular resection (11,22). The rarity of complete heart block (and the necessity for pacemakers) after myectomy is related to the experience and ability of the surgeon to avoid complete interruption of the conduction system.

The morphologic appearance after alcohol septal ablation on CMR scanning is one of a myocardial infarction. It is unknown whether the long-term consequences of myocardial infarction from septal ablation may produce an arrhythmogenic substrate and possible trigger for sudden cardiac death (3,23). There have been several reports of sustained ventricular arrhythmias and even sudden death shortly after alcohol ablation (24,25). At the present time, however, the relatively short-term follow-up available after septal ablation precludes precise knowledge regarding the magnitude of that risk, especially because sudden death caused by ventricular arrhythmia may occur in HCM unpredictably decades after diagnosis (2,4). Systematic long-term follow-up studies of patients undergoing this procedure will be necessary to determine whether the alcohol-induced myocardial infarction poses an increased risk for ventricular arrhythmias of sudden death.

Study limitations. The CMR studies comprising this investigation were assembled prospectively, but were not obtained consecutively, largely because of certain unavoidable patient exclusion criteria for CMR imaging. These patients may not represent the overall population undergoing ablation as 17% of patients were excluded because of the requirement for a permanent pacemaker. Clinical follow-up and repeat follow-up CMR studies were incomplete, but the major purpose of this study was to examine the acute anatomical effect of the 2 septal reduction therapies. There is a learning curve to performing alcohol septal ablation, and the optimal results occur with experienced operators (26,27). This current study was performed when more than 100 alcohol septal ablations had been performed by the operators. Nonetheless, further improvements in the technique of performing septal ablations may result in better outcomes.

Conclusions. Surgical septal myectomy and alcohol septal ablation for severely symptomatic drug-refractory patients with obstructive HCM have different effects on ventricular septal myocardium. Septal myectomy provides a consistent resection of the obstructing portion of the anterior basal septum. The effect of alcohol septal ablation is more variable with sparing of the basal septum in some patients. The mechanism of septal ablation is creation of a transmural region of tissue necrosis, located more inferiorly than myectomy. Differences in anatomical sequelae between these 2 treatment modalities may have important potential implications for patient selection and management, as for well as long-term outcome.

Reprint requests and correspondence: Dr. Rick A. Nishimura, 200 First Street SW, Rochester, Minnesota 55905. E-mail: rnishimura@mayo.edu.

REFERENCES

1. Nishimura RA, Holmes DR Jr. Clinical practice. Hypertrophic obstructive cardiomyopathy. N Engl J Med 2004;350:1320–7.
2. Maron BJ. Hypertrophic cardiomyopathy: a systematic review. JAMA 2002;287:1308–20.
3. Maron BJ, Dearani JA, Ommen SR, et al. The case for surgery in obstructive hypertrophic cardiomyopathy. J Am Coll Cardiol 2004;44:2044–53.
4. Maron BJ, McKenna WJ, Danielson GK, et al. American College of Cardiology/European Society of Cardiology clinical expert consensus document on hypertrophic cardiomyopathy. A report of the American College of Cardiology Foundation Task Force on Clinical Expert Consensus Documents and the European Society of Cardiology Committee for Practice Guidelines. J Am Coll Cardiol 2003;42:1687–713.
5. Ommen SR, Maron BJ, Olivotto I, et al. Long-term effects of surgical septal myectomy on survival in patients with obstructive hypertrophic cardiomyopathy. J Am Coll Cardiol 2005;46:470–6.
6. Seggewiss H, Gleichmann U, Faber L, Fassbender D, Schmidt HK, Strick S. Percutaneous transluminal septal myocardial ablation in

hypertrophic obstructive cardiomyopathy: acute results and 3-month follow-up in 25 patients. J Am Coll Cardiol 1998;31:252–8.
7. Sigwart U. Non-surgical myocardial reduction for hypertrophic obstructive cardiomyopathy. Lancet 1995;346:211–4.
8. Kuhn H, Gietzen FH, Leuner C, et al. Transcoronary ablation of septal hypertrophy (TASH): a new treatment option for hypertrophic obstructive cardiomyopathy. Z Kardiol 2000;89:IV41–54.
9. Hess OM, Sigwart U. New treatment strategies for hypertrophic obstructive cardiomyopathy: alcohol ablation of the septum: the new gold standard? J Am Coll Cardiol 2004;44:2054–5.
10. Morrow AG, Roberts WC, Ross J Jr., et al. Obstruction to left ventricular outflow. Current concepts of management and operative treatment. Ann Intern Med 1968;69:1255–86.
11. Talreja DR, Nishimura RA, Edwards WD, et al. Alcohol septal ablation versus surgical septal myectomy: comparison of effects on atrioventricular conduction tissue. J Am Coll Cardiol 2004;44: 2329–32.
12. Ommen SR, Park SH, Click RL, Freeman WK, Schaff HV, Tajik AJ. Impact of intraoperative transesophageal echocardiography in the surgical management of hypertrophic cardiomyopathy. Am J Cardiol 2002;90:1022–4.
13. Nagueh SF, Lakkis NM, He ZX, et al. Role of myocardial contrast echocardiography during nonsurgical septal reduction therapy for hypertrophic obstructive cardiomyopathy. J Am Coll Cardiol 1998;32: 225–9.
14. Simonetti OP, Kim RJ, Fieno DS, et al. An improved MR imaging technique for the visualization of myocardial infarction. Radiology 2001;218:215–23.
15. Cerqueira MD, Weissman NJ, Dilsizian V, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation 2002;105:539–42.
16. Kim RJ, Fieno DS, Parrish TB, et al. Relationship of MRI delayed contrast enhancement to irreversible injury, infarct age, and contractile function. Circulation 1999;100:1992–2002.
17. Choudhury L, Mahrholdt H, Wagner A, et al. Myocardial scarring in asymptomatic or mildly symptomatic patients with hypertrophic cardiomyopathy. J Am Coll Cardiol 2002;40:2156–64.
18. van Dockum WG, Beek AM, ten Cate FJ, et al. Early onset and progression of left ventricular remodeling after alcohol septal ablation in hypertrophic obstructive cardiomyopathy. Circulation 2005;111: 2503–8.
19. van Dockum WG, ten Cate FJ, ten Berg JM, et al. Myocardial infarction after percutaneous transluminal septal myocardial ablation in hypertrophic obstructive cardiomyopathy: evaluation by contrast-enhanced magnetic resonance imaging. J Am Coll Cardiol 2004;43: 27–34.
20. Seggewiss H, Faber L, Gleichmann U. Percutaneous transluminal septal ablation in hypertrophic obstructive cardiomyopathy. Thorac Cardiovasc Surg 1999;47:94–100.
21. Qin JX, Shiota T, Lever HM, et al. Conduction system abnormalities in patients with obstructive hypertrophic cardiomyopathy following septal reduction interventions. Am J Cardiol 2004;93:171–5.
22. McCully RB, Nishimura RA, Tajik AJ, Schaff HV, Danielson GK. Extent of clinical improvement after surgical treatment of hypertrophic obstructive cardiomyopathy. Circulation 1996;94:467–71.
23. Maron BJ. Surgery for hypertrophic obstructive cardiomyopathy: alive and quite well. Circulation 2005;111:2016–8.
24. Boltwood CM Jr., Chien W, Ports T. Ventricular tachycardia complicating alcohol septal ablation. N Engl J Med 2004;351:1914–5.
25. McGregor JB, Rahman A, Rosanio S, Ware D, Birnbaum Y, Saeed M. Monomorphic ventricular tachycardia: a late complication of percutaneous alcohol septal ablation for hypertrophic cardiomyopathy. Am J Med Sci 2004;328:185–8.
26. Kuhn H, Seggewiss H, Gietzen FH, Boekstegers P, Neuhaus L, Seipel L. Catheter-based therapy for hypertrophic obstructive cardiomyopathy. First in-hospital outcome analysis of the German TASH Registry. Z Kardiol 2004;93:23–31.
27. Nagueh SF, Ommen SR, Lakkis NM, et al. Comparison of ethanol septal reduction therapy with surgical myectomy for the treatment of hypertrophic obstructive cardiomyopathy. J Am Coll Cardiol 2001;38:1701–6.